
BIOMAGNETISM

CLINICAL ASPECTS

Editors:

**M.HOKE, S.N.ERNÉ,
Y.C.OKADA and G.L.ROMANI**

EXCERPTA MEDICA

International Congress Series 988

Biomagnetism: Clinical Aspects

Proceedings of the 8th International Conference on Biomagnetism,
Münster, 19–24 August 1991

Editors:

Manfried Hoke

Institut für Experimentelle Audiologie
Westfälische Wilhelms-Universität Münster
Münster, Germany

Sergio Nicola Erné

Zentralinstitut für Biomedizinische Technik
Universität Ulm
Ulm, Germany

Yoshio C. Okada

MEG Center, VA Medical Center
New Mexico University
Albuquerque, NM, USA

Gian Luca Romani

Istituto Tecnologie Avanzate Biomediche
Facoltà di Medicina e Chirurgia
Università degli Studi "G. d'Annunzio"
Chieti, Italy



1992

EXCERPTA MEDICA, Amsterdam – London – New York – Tokyo

© 1992 Elsevier Science Publishers B.V. All rights reserved.

No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without the prior written permission of the publisher, Elsevier Science Publishers B.V., Permissions Department, P.O. Box 521, 1000 AM Amsterdam, The Netherlands.

No responsibility is assumed by the Publisher for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in the material herein. Because of rapid advances in the medical sciences, the Publisher recommends that independent verification of diagnoses and drug dosages should be made.

Special regulations for readers in the USA – This publication has been registered with the Copyright Clearance Center Inc. (CCC), 27 Congress Street, Salem, MA 01970, USA. Information can be obtained from the CCC about conditions under which photocopies of parts of this publication may be made in the USA. All other copyright questions, including photocopying outside the USA, should be referred to the copyright owner, Elsevier Science Publishers B.V., unless otherwise specified.

International Congress Series No. 988
ISBN 0-444-89268-0

This book is printed on acid-free paper.

Published by:
Elsevier Science Publishers B.V.
P.O. Box 211
1000 AE Amsterdam
The Netherlands

Sole distributors for the USA and Canada:
Elsevier Science Publishing Company Inc.
655 Avenue of the Americas
New York, NY 10010
USA

Preface

This volume comprises papers presented at the 8th International Conference on Biomagnetism, held from 18 to 24th August 1991, at the University of Münster, Germany, and attended by approximately 400 participants from more than 30 countries. A total of 240 invited lectures and contributed papers (including posters) were presented, but only a selection of 142 manuscripts are included in this volume. This change in the publication policy of the proceedings became necessary because of a physical limit imposed by the size of the book (there were about 80 contributions in Vancouver, 170 in Tokyo, 185 in New York). This issue was exhaustively discussed at the preceding conference in New York, and the majority of participants agreed that future proceedings should be restricted to a selection preferably of those papers which were directly related to the main subject of the conference.

The New York Conference celebrated the 20th anniversary of the first application of a SQUID (Superconducting QUantum Interference Device) to biomagnetism. The year of the Münster Conference was also characterized by the coincidence of several anniversaries with some significance for biomagnetism. Two hundred years earlier, in 1791, the Italian scientist Luigi Galvani discovered what he believed to be “animal electricity” (only a few years after Franz Anton Mesmer postulated the existence of an “animal magnetism”)¹. One-hundred-and-twenty years later, in 1911, the Dutch physicist Heike Kamerlingh Onnes discovered superconductivity, one of the essential prerequisites for measuring the extremely weak biomagnetic signals. Last, but not least, 15 years before the Münster conference, in 1976, the first meeting of this series took place in Boston, Massachusetts, then being more a forum for discussion rather than a formal conference.

Biomagnetic research had started well before this first conference. Its year of birth can be dated back to 1963 when Baule and McFee succeeded in measuring real “animal” magnetism, the magnetocardiogram. With the passing of almost three decades since then, the new emerging discipline of biomagnetism has undergone a remarkable development. Originally, biomagnetic research was confined to laboratories belonging to physical or engineering sciences, basically owing to the fact that the necessary equipment was not yet on the market. This situation changed drastically when SQUID systems for biomagnetic studies became commercially available. Biomagnetic research then began to spread out to biosciences. The proceedings of the two previous conferences with their increasing portion of papers related especially to neuromagnetism and to cardiomagnetism, and also to other aspects of biomagnetic applications e.g. biosusceptometry, bear eloquent witness of this de-

¹Interestingly enough, both were wrong with their ideas. Mesmer’s magnetism existed only in his imagination, while Galvani’s electricity was produced solely by his instrument acting as a local element.

velopment. Biomagnetic research in a clinical environment, however, could not flourish before another obstacle was overcome: Data collection as it was originally done with single-channel systems was not only too laborious, it was often unacceptable for the patient, and many phenomena – especially spontaneous activity – could not be adequately studied. The advent of multi-channel (24–37) systems, which became available just prior to the New York Conference, signifies a quantum jump for the biomagnetic research in clinical environments.

Hence, at the 8th Conference on Biomagnetism, it was consistent to put the emphasis on clinical aspects. There are certainly more reasons for emphasizing clinical research, reasons which are, in part, closely interrelated. Powerful biomagnetic equipment is extremely expensive, and the price is actually higher than that of MRI and PET instruments. While, for those instruments, clear-cut clinical applications exist which are recognized and paid for by health insurance funds, no clear-cut clinical applications exist so far for biomagnetism. It was the aim of the Scientific Committee to take stock of the actual clinical research in biomagnetism in order to see whether clinical applications can be foreseen in the near future. Only if clinical applications of biomedical techniques can be developed which are superior to, and cannot be replaced by, other available techniques, then there are chances that development and improvement of biomagnetic systems will further continue and that a substantial price reduction can be achieved. Further development as well as a substantial price reduction of biomagnetic systems, on the other hand, are prerequisites for their widespread use.

This is, therefore, a decisive time for the future of biomagnetism. As already mentioned, further development and improvement of systems for biomagnetic research is necessary to achieve another quantum jump from a scientific instrument to a powerful and irreplaceable clinical tool. Many steps are needed to achieve this quantum jump, including the development of systems covering the whole head² or whole chest, and developments allowing the reduction of costs for purchase and maintenance of these systems. The development of low-noise High-Tc SQUIDs³ would be one possible step in this direction.

The majority of papers presented at this conference were devoted to neuromagnetism, cardiomagnetism and biosusceptometry. It is noteworthy that promising research has also begun in other medical disciplines, especially in gastroenterology. However, the conference also revealed that the big step forward has not yet been made. The time has not come yet for widespread clinical applications of biomagnetic techniques. More than developments in instrumentation are required for establishing clinical applications, and models for the interpretation of data play a crucial role. It is the greatest challenge for biomagnetic research to develop strategies which produce confident findings on which a diagnostic or therapeutic decision can be based.

These comments, however, do not at all imply that biomagnetism has no future. The superiority of biomagnetic (like bioelectric) techniques – as compared with imaging techniques like MRI and PET – lies in its unequalled temporal resolution, though the lead has become distinctly smaller. Information obtained from echo planar imaging (which requires no more than 25 ms for one slice) could be extremely helpful for the development of reliable source models for biomagnetic localization.

A conference of 400 participants can be successful only by virtue of dedicated collaboration of many individuals. A significant contribution to the success of the conference was made by the members of the Scientific Committee by reviewing the submitted abstracts. We also wish to thank all members of the Organizing Committee and the members of the Institute of Experimental Audiology of the University of Münster for their tireless efforts before and during the conference. Georg Kämmerer deserves special acknowledgement for editing the submitted manuscript files, of which many were unreadable. Finally, a conference like this could not be organized without the substantial support of sponsors and exhibitors, whose substantial contributions are gratefully acknowledged.

Manfried Hoke
Sergio N. Erné
Yoshio Okada
Gian Luca Romani

²The first whole-head system became operative just prior to the appearance of this volume.

³Also the first reports about successful applications of High-Tc SQUIDs for neuromagnetic and cardiomagnetic measurements have just appeared.

Conference organization

Chairman

Manfried Hoke
Institute of Experimental Audiology
University of Münster
4400 Münster
Germany

Organizing committee

Manfried Hoke
Helga Janutta
Georg Kämmerer
Bernd Lütkenhöner

Christo Pantev
Ellen S. Proefrock
Anette Sütfeld

Scientific committee

Chairman
Manfried Hoke
Institute of Experimental Audiology
University of Münster
4400 Münster
Germany

Sergio N. Ern 
Zentralinstitut f r Biomedizinische
Technik
Universit t Ulm
7900 Ulm
Germany

Hisashi Kado
Superconducting Sensor Laboratory
2-1200 Muzaigakuendai
Inzai, Chiba 270-13
Japan

Toivo Katila
Department of Technical Physics
Helsinki University of
Technology
SF-02150 Espoo 15
Finland

Yutaka Nakaya
2nd Department of Internal Medicine
Tokushima University
Tokushima
Japan

Yoshio C. Okada
MEG Center (101)
Veterans Affairs Medical Center
Albuquerque, NM 87108
USA

Gian Luca Romani
Istituto Tecnologie Avanzate
Biomediche
Facolt  di Medicina e Chirurgia
Universita degli Studi
“G. d’Annunzio”
I-66100 Chieti
Italy

Gerhard Stroink
Department of Physics
Dalhousie University
Halifax, Nova Scotia B3H 3J5
Canada

Advisory committee

Chairman
S.J. Williamson
Neuromagnetism Laboratory
Department of Physics
New York University
New York, NY 10003
USA

Kazuhiko Atsumi
Faculty of Medicine
University of Tokyo
7-3-1 Hongo, Bunkyo-ku
Tokyo 113
Japan

Dr. David Cohen
Francis Bitter National Magnet
Laboratory
M.I.T., NW14-2217
Cambridge, MA 02139
USA

J.P. Wikswo Jr.
Department of Physics and
Astronomy
Vanderbilt University
Nashville, TN 37235
USA

S.J. Williamson
Neuromagnetism Laboratory
Department of Physics
New York University
New York, NY 10003
USA

Sergio N. Ern 
Zentralinstitut f r Biomedizinische
Technik
Universit t Ulm
7900 Ulm
Germany

Manfried Hoke
Institute of Experimental
Audiology
University of Münster
4400 Münster
Germany

Toivo Katila
Department of Technical Physics
Helsinki University of
Technology
SF-02150 Espoo 15
Finland

Gian Luca Romani
Istituto Tecnologie Avanzate
Biomediche
Facoltà di Medicina e Chirurgia
Università degli Studi
“G. d’Annunzio”
I-66100 Chieti
Italy

Shoogo Ueno
Department of Electronics
Faculty of Engineering
Kyushu University
Fukuoka 812
Japan

Sponsors

Commission of the European Communities

Asta
Bayer
Biomagnetic Technologies
CTF Systems Inc.
Deutsche Apotheker-und Ärztebank
Farmitalia Carlo Erba
IAC
Kontron Elektronik
Köttgen Hörakustik
M. Lückertz
Metropolis
3M Medica
Neuromag
Neuroscan
Philips
Rhone-Poulenc Rorer
Siemens
Technoflex
Vacuumschmelze
Westra

Prof. Harold Weinberg
Brain Behavior Laboratory
Simon Fraser University
Burnaby, BC V5A 1S6
Canada

J.P. Wikswo Jr.
Department of Physics and
Astronomy
Vanderbilt University
Nashville, TN 37235
USA

Contents

NEUROMAGNETISM

Development of a new science of brain dynamics with guidance from the theory of nonlinear dynamics and chaos <i>W.J. Freeman</i>	3
Mathematical aspects of biomagnetic and bioelectric modeling <i>J.C. de Munck and M.J. Peters</i>	13

Spontaneous EEG-MEG

EEG/MEG and alpha activity: Current status of biomagnetic research <i>R.M. Chapman</i>	25
Neuronal sources of parietooccipital alpha rhythm <i>Z.-L. Lü, J.-Z. Wang and S.J. Williamson</i>	33
Separation of sources of alpha activity in multichannel MEG <i>P. Grummich, J. Vieth, H. Kober and T. Scholz</i>	39

Epilepsy

Pathophysiology of epilepsies <i>E.-J. Speckmann, U. Altrup, H. Straub, D. Bingmann, J. Walden, A. Lücke, M. Pohl, H. Wassmann and D. Moskopp</i>	45
Facts in epileptology which are of possible relevance for biomagnetism <i>C.E. Elger</i>	53
Current status of biomagnetic research in epileptology <i>S. Sato</i>	61
Detection of epileptiform discharges by magnetoencephalography in comparison to invasive measurements <i>C. Baumgartner, D.S. Barth, M.F. Levesque and W.W. Sutherling</i>	67
Contribution of different areas of epileptic foci to the generation of interictal epileptic discharges <i>O.W. Witte, T. Dorn and S. Uhlig</i>	73
Localization and quantification of the human epileptic spike zone using MEG, EEG, MRI and evoked responses with validation by ECoG <i>N. Nakasato, L. Muresan, L. Vinet, C. Baumgartner, D. Barth and W.W. Sutherling</i>	79
Simultaneous MEG and ECoG of spontaneous seizures and comparison with MEG and ECoG of auditory evoked response (AER) <i>N. Nakasato, L. Muresan, C. Baumgartner, D.S. Barth and W.W. Sutherling</i>	83

Ictal and interictal multichannel magnetic field recordings of epileptiform activity: Quantitative description of centers of focal epileptic activity	
<i>H. Stefan, P. Schüler, K. Abraham-Fuchs and S. Schneider</i>	87
Magnetoencephalographic localization of epileptic dipole activity in patients with pharmacoresistant epilepsy: Foci and pathways	
<i>E. Hellstrand, K. Abraham-Fuchs, S. Schneider, E. Knutsson, C. Lindquist and L. Kihlström</i>	93
MEG template analysis in focal and generalized epilepsy: Results in 27 cases	
<i>G.B. Ricci, C. Del Gratta, A. Pasquarelli, M. Peresson, V. Pizzella, G. Torrioli and G.L. Romani</i>	97

Evoked potentials and fields

Reflection of automatic change detection in the human brain: Event-related potentials and magnetic responses	
<i>V. Csépe and R. Näätänen</i>	103
Cognitive processes: Current status of neuromagnetic research	
<i>M. Sams</i>	111
Evoked potentials: Diagnostic uses and strategies	
<i>F. Mauguière</i>	121
Evoked potentials and fields in the somatosensory and visual systems: Current status of biomagnetic research	
<i>P.M. Rossini</i>	133

Auditory evoked fields and related phenomena

The exogenous components of the auditory evoked field: Current status	
<i>B. Lütkenhöner and C. Pantev</i>	143
Evidence of gamma-band oscillations in the transient human auditory evoked magnetic field	
<i>C. Pantev, S. Makeig, M. Hoke, R. Galambos, S. Hampson and C. Gallen</i>	153
The spatial and temporal organization of the 40 Hz response in human brain: An MEG study	
<i>U. Ribary, R. Llinàs, F. Lado, A. Mogilner, R. Jagow, M. Nomura and L. Lopez</i>	159
The auditory complex event-related field to omitted steady-state probes	
<i>S. Makeig, C. Pantev, B. Schwartz, M. Inlow, S. Hampson and C. Gallen</i>	165
Reliability and validity of auditory neuromagnetic source localization using a large array biomagnetometer	
<i>C. Gallen, C. Pantev, S. Hampson, D.S. Buchanan and D. Sobel</i>	171

Source estimation of late components of omitted tone evoked magnetic fields	
<i>A.C. Papanicolaou, S.B. Baumann and R.L. Rogers</i>	177
Spatiotemporal source localization of neuromagnetic fields evoked by pure tones	
<i>F. Takeuchi, M. Mukai, S. Kuriki, M. Hayashi and T. Imada</i>	181
Auditory evoked fields in normals and patients: Preliminary findings	
<i>G. Paludetti, L. Corina, C. Del Gratta, J. Galli, A. Pasquarelli, R. Pellini, M. Peresson, V. Pizzella, M. Maurizi and G.L. Romani</i>	185
Changes in cortical activity when subjects scan memory for tones	
<i>L. Kaufman, S. Curtis, J.-Z. Wang and S.J. Williamson</i>	189

Visual evoked fields and related phenomena

Visual evoked magnetic fields with red-black and green-black pattern-reversal stimulation	
<i>K. Hatanaka, K. Seki, N. Nakasato and T. Yoshimoto</i>	197
Neuromagnetic evoked visual fields following infrequent stimulus omissions	
<i>R.L. Rogers, A. Papanicolaou, S. Baumann and H. Eisenberg</i>	203
Neuromagnetic responses associated with temporal integration of visual stimuli	
<i>H. Weinberg, B. Johnson, D. Cheyne, G. Carrier and D. Crisp</i>	207
Magnetic brain responses in visual spatial attention	
<i>A.A. Wijers, Z. Dunajski, M. Peters and G. Mulder</i>	213
Cortical alpha-frequency oscillations evoked by visual pattern stimuli	
<i>S.P. Ahlfors, R.J. Ilmoniemi and M.S. Hämäläinen</i>	217

Somatosensory evoked fields and related phenomena

Oscillotopic organization of the human somatosensory cortex of lip using the neuromagnetic method	
<i>M. Nomura, U. Ribary, L. Lopez, A. Mogilner, F. Lado, R. Jagow and R. Llinàs</i>	223
Magnetic responses reveal somatotopic organization of the second somatosensory cortex	
<i>R. Hari, J. Karhu, M. Sams, M. Hämäläinen and J. Knuutila</i>	229
Comparison of EEG, ECoG, MRI, and seven versus 31 channels of MEG for noninvasive localization of the somatosensory evoked response	
<i>W.W. Sutherling, N. Nakasato, L. Muresan, L. Vinet, C. Baumgartner and D. Barth</i>	233
Combined neuromagnetic and neuroelectric study of human cortical digit representation	
<i>C. Baumgartner, A. Doppelbauer, W.W. Sutherling, J. Zeitlhofer, G. Lindinger and L. Deecke</i>	237

Neuromagnetic mapping under mixed median nerve stimulation: Influence of stimulus intensity on sources parameters <i>M. Peresson, S. Casciardi, C. Del Gratta, S. Di Luzio, M.A. Macrì, V. Pizzella, G.L. Romani and P.M. Rossini</i>	241
Hemispheric asymmetries of somatosensory evoked fields to median nerve stimulation: Normative data in healthy volunteers and preliminary clinical applications <i>P.M. Rossini, C. Del Gratta, V. Foglietti, C. Iani, L. Pacifici, A. Pasquarelli, F. Passarelli, M. Peresson, V. Pizzella, G. Torrioli, and G.L. Romani</i>	247
Reliability of somatosensory neuromagnetic source localization using a multisensor biomagnetometer <i>B. Schwartz, C. Gallen, S. Hampson, E. Hirschkoff, D. Sobel and K. Rieke</i>	253
Early somatosensory evoked magnetic fields studied with a multichannel first-order gradiometer system <i>R. Laudahn, I.M. Tarkka, W.H. Kullmann, M. Fuchs, O. Dössel and B. Bromm</i>	259
Pain evoked fields	
Late magnetic field components evoked by auditory and pain-inducing stimuli <i>B. Bromm, R. Laudahn and I.M. Tarkka</i>	265
Whole-head studies of pain-related evoked magnetic fields <i>R.T. Wakai, E.W. Howland, S.J. Swerdloff, J. Balog, D. Bensinger and C.S. Cleeland</i>	269
Motor system	
Bilateral organization of unilateral voluntary movements <i>R. Kristeva, D. Cheyne and L. Deecke</i>	275
SMA activity in voluntary movements as localized by MEG <i>W. Lang, D. Cheyne, R. Kristeva, R. Beisteiner, G. Lindinger and L. Deecke</i>	279
A comparison of magnetic fields and electric potentials preceding voluntary eye, eyelid and finger movements <i>W. Becker, B. Grözing, C. Kornhuber, V. Diekmann and R. Jürgens</i>	283
Magnetic fields of the human brain preceding voluntary finger extension <i>I. Hashimoto, K. Odaka, T. Mashiko, T. Imada, T. Gatayama and S. Yokoyama</i>	287
Neuromagnetic H-reflex responses in man <i>B.-E. Will and H. Prehn</i>	293

MEG and brain pathologies

Detection and localization of delta frequency activity in human strokes <i>C. Gallen, B. Schwartz, C. Pantev, S. Hampson, D. Sobel, E. Hirschkoff, K. Rieke, S. Otis and F. Bloom</i>	301
Somatosensory evoked magnetic fields in multiple sclerosis <i>J. Karhu, R. Hari, J.P. Mäkelä, J. Huttunen and J. Knuutila</i>	307
Auditory steady-state responses in subjects with early Alzheimer's disease <i>S.B. Baumann, A.C. Papanicolaou, H.S. Levin, L.A. Bertolino, R.L. Rogers and B.E. Masel</i>	313
Auditory evoked field (M100/M200) measurements in tinnitus and normal groups <i>G.P. Jacobson, B.K. Ahmad, J. Moran, C.W. Newman, J. Wharton and N. Tepley</i>	317
The efficacy of the discrete and the quantified continuous dipole density plot (DDP) in multichannel MEG <i>J. Vieth, H. Kober, G. Sack, P. Grummich, S. Friedrich, A. Möger, E. Weise, A. Daun and H. Pongratz</i>	321

Spreading depression and related DC phenomena

Spreading depression and related DC phenomena <i>N. Tepley</i>	329
The measurement of tonic brain activity by means of magnetoencephalography <i>T. Elbert, C. Braun, B. Rockstroh and S. Schneider</i>	337

Peripheral nerves

Electric current flow in peripheral nerves <i>H. Meves</i>	343
Peripheral nerves: Current status of clinical diagnosis <i>R. Dengler and M. Kempkes</i>	349
Modeling of the magnetic field produced by peripheral nerves <i>J.M. van Egeraat, R.S. Wijesinghe and J.P. Wikswo Jr.</i>	357
Peripheral nerve and early spinal cord activity in man: Current status of biomagnetic research <i>G. Curio</i>	365

Animal studies in neurophysiology

A high-resolution system for magnetophysiology and its applications <i>Y.C. Okada, S. Kyuhou, A. Lähteenmäki and C. Xu</i>	375
---	-----

Measurement of nonuniform propagation in the squid nervous system with a room temperature magnetic current probe <i>J.M. van Egeraat and J.P. Wikswo Jr.</i>	385
Observation of magnetic field changes associated with KCl induced spreading depression in anesthetized rats <i>Y. Takanashi, Q. Chen, M. Chopp, S.R. Levine, J.E. Moran N. Tepley and K.M.A. Welch</i>	389
DC neuromagnetic field changes during reversible anoxia in anesthetized rats <i>Y. Takanashi, M. Chopp, Q. Chen, G.L. Barkley, S.R. Levine, J. Kim, J.E. Moran and N. Tepley</i>	393
CARDIOMAGNETISM	
Cardiomagnetism: A historical perspective <i>G. Stroink</i>	399
Torso modeling in electrocardiography <i>A. van Oosterom and G.J. Huiskamp</i>	405
Torso and heart models in magnetocardiography <i>J. Nenonen, B.M. Horacek and T. Katila</i>	417
Cardiac arrhythmias and localization	
Electrophysiologic mechanisms of ventricular arrhythmias <i>N. El-Sherif</i>	429
Application of multichannel systems in magnetocardiography <i>W. Moshage, S. Achenbach, S. Schneider, K. Göhl, K. Abraham-Fuchs, R. Graumann and K. Bachmann</i>	439
Magnetocardiography in combination with MRI: Verification of localization accuracy with a nonmagnetic pacing catheter <i>W. Moshage, S. Achenbach, K. Göhl, W. Härer, S. Schneider and K. Bachmann</i>	447
Magnetocardiographic investigation of the origin and propagation of cardiac arrhythmias <i>S. Achenbach, W. Moshage, K. Göhl, K. Abraham-Fuchs, S. Schneider and K. Bachmann</i>	453
Magnetocardiographic localization of single ventricular premature beats with a multichannel system in patients with ventricular tachycardia <i>P. Weismüller, K. Abraham-Fuchs, S. Schneider, P. Richter, W. Härer, M. Kochs, J. Edrich and V. Hombach</i>	459
Magnetocardiographic localization of ventricular tachycardias with a multichannel system <i>P. Weismüller, K. Abraham-Fuchs, S. Schneider, P. Richter, W. Härer, M. Kochs, J. Edrich and V. Hombach</i>	465

Magnetic field and body surface potential mapping of patients with ventricular tachycardia <i>G. Stroink, J. Lant, P. Elliott, R. Lamothe and M. Gardner</i>	471
Magnetocardiographic localization of premature ventricular contraction in a patient with ventricular tachycardia <i>T. Kokubun, N. Awano, K. Kido, Y. Maruyama, R. Horiuchi, S. Kiryu and N. Kasai</i>	477
High-resolution magnetocardiography can identify ventricular tachycardia patients after myocardial infarction <i>M. Mäkijärvi, J. Montonen, L. Toivonen, M. Leiniö, P. Siltanen and T. Katila</i>	483
Magnetocardiogram in antero-septal and inferior infarctions <i>O.S. Oja, J. Nousiainen, J. Malmivuo and A. Uusitalo</i>	487
MCG localization of accessory pathways using a realistic torso <i>M. Mäkijärvi, J. Nenonen, K. Forsman, L. Toivonen, P. Keto, P. Hekali, P. Siltanen, J. Montonen, M. Leiniö and T. Katila</i>	491
Comparative analysis of the spatial sensitivities of VMCG and VECG <i>J. Nousiainen, O.S. Oja and J. Malmivuo</i>	497
Dynamic magnetocardiography <i>K. Brockmeier, S. Casciardi, S. Comani, C. Del Gratta, L. Di Donato, S. Di Luzio, S.N. Erné, A. Pasquarelli, M. Peresson and G.L. Romani</i>	503
Application of dynamic magnetocardiography in a trained athlete with repolarization disturbances: A case report <i>K. Brockmeier, S. Comani, C. Del Gratta, L. Di Donato, S. Di Luzio, A. Pasquarelli, V. Pizzella and G.L. Romani</i>	509
ECG/MCG and risk analysis	
The value of signal-averaged electrocardiography and programmed electrical stimulation in the assessment of risk for sudden death <i>A.J. Camm</i>	515
Magnetocardiography and risk analysis <i>M. Mäkijärvi</i>	523
Magnetocardiography in healthy subjects: Validation of "risk analysis" <i>S. Comani, K. Brockmeier, C. Del Gratta, S. Di Luzio, S.N. Erné, A. Mezzetti, V. Pizzella, A. Scarinci and G.L. Romani</i>	531
Heart transplantation and graft rejection	
Rejection diagnosis after heart transplantation: New aspects and methods <i>J. Müller, H. Warnecke and R. Hetzer</i>	537

Magnetocardiographic diagnosis of graft rejection after heart transplantation

L. Schmitz, H. Koch, K. Brockmeier, J. Müller, S. Schüler, H. Warnecke, R. Hetzer and S.N. Ern 

555

Miscellaneous

Volume current effects on the fetal magnetocardiogram

Z. Dunajski and M. Peters

565

BIOSUSCEPTOMETRY

Biosusceptometry – current status of clinical diagnostics and biomagnetic research

R. Fischer and H.C. Heinrich

573

Liver susceptometry

Liver iron quantification in the diagnosis and therapy control of iron overload patients

R. Fischer, R. Engelhardt, P. Nielsen, E.E. Gabbe, H.C. Heinrich, W.H. Schmieg l and D. Wurbs

585

Liver susceptometry for the follow up of transfusional iron overload

W. Hartmann, L. Schneider, A. Wirth, M. D rdelmann, D. Zinser, H. Elias, W. Languth, W. Ludwig and E. Kleihauer

589

Magnetic tracers in gastroenterology

Physiology and pathophysiology of intestinal motility

J. Christensen

597

Clinical diagnosis of intestinal motility disorders: Current techniques and future perspectives

M. Neri, A. Mezzetti, E. Porreca and F. Cuccurullo

605

The biomagnetic approach to the study of gastrointestinal activity

M. Basile

613

The biomagnetic method for the study of gastrointestinal transit

M.A. Macr , M. Basile, S. Casciardi, S. Comani, C. Del Gratta, L. Di Donato, S. Di Luzio, M. Neri, A. Pasquarelli, V. Pizzella and G.L. Romani

621

Gastrointestinal motility displayed by magnetic marker dislocations monitored by multichannel systems

L. Trahms, R. Model, R. Stehr, J. Wedemeier and W. Weitschies

625

A biomagnetic technique for orocaecal transit time measurement

R.B. Oliveira, J.R.A. Miranda, O. Baffa, C.R. Cambrea and L.E.A. Troncon

631

Susceptometric measurement of gastric emptying

J.R.A. Miranda, R.B. Oliveira, N.M. Matsuda and O. Baffa

635

Extracorporeal direct magnetic measurement of gastric activity

S. Comani, M. Basile, S. Casciardi, C. Del Gratta, S. Di Luzio, S.N. Ern , M. Neri, M. Peresson and G.L. Romani

639

Miscellaneous

Biomagnetic measurements utilizing ferrofluids

M. Chopp, Q. Chen, J.E. Moran and N. Tepley

645

Use of a magnetic tracer in hemodynamics: A model study

C. Del Gratta, M. Basile, S. Comani, S. Di Luzio, S.N. Ern , M.A. Macr , A. Pasquarelli and G.L. Romani

651

In vivo measurement of hydrodynamic properties and activity of alveolar macrophages

W. M ller and W. Stahlhofen

655

Magnetopneumography with spherical monodisperse ferrimagnetic particles

W. Stahlhofen and W. M ller

661

RELATED TECHNIQUES

PET as competitor to MEG?

P. Bartenstein and O. Schober

669

Electrical impedance tomography and biomagnetism

J.G. Webster

675

MODELING, THEORY AND DATA PROCESSING

On the biomagnetic inverse procedure's capability of separating two current dipoles with a priori known locations

B. L tkenh ner

687

Multiple dipole estimation by parameter search method

O. Oshiro, M. Mukai, F. Takeuchi and S. Kuriki

693

Reducible integral equation for a dipole in a quasispherical conductor

C.W. Crowley and J. Budiman

699

Estimation of the ratio of the number of firing nerve fibers in contralateral and ipsilateral auditory pathways based on a MEG source model

K. Iramina, S. Iwaki and S. Ueno

705

A strategy for the solution of the inverse problem using simultaneous EEG and MEG measurements <i>S.L. Gonzalez-Andino, R.D. Pascual-Marqui, R. Grave de Peralta, B. Lütkenhöner, E. Menninghaus and M. Hoke</i>	711	Synthetic magnetometer channels for standard representation of data <i>R.J. Ilmoniemi and J.K. Numminen</i>	793
Spatiotemporal source modelling of sensorimotor cortex activation accompanying human voluntary movement <i>D. Cheyne, R. Kristeva, L. Deecke and H. Weinberg</i>	717	Accurate and efficient formulas for averaging the magnetic field over a circular coil <i>B.J. Roth and S. Sato</i>	797
Simulation of activity of visual cortex <i>J.-Z. Wang, L. Kaufman and J.H. Kaufman</i>	723	Finite difference field mapping <i>J.E. Moran, G.P. Jacobson and N. Tepley</i>	801
A hierarchical minimum norm estimation method for reconstructing current densities in the brain from remotely measured magnetic fields <i>Y. Okada, J. Huang and C. Xu</i>	729	Influence of sampling rate and filtering on the correlation dimension of the human alpha EEG and MEG <i>K. Lehnertz</i>	807
Exploiting lead field analysis to obtain current source reconstructions and a figure of merit <i>C. Tesche</i>	735	Is there a need for individualized torso models in magnetic inverse solutions? <i>G. Stroink, L.S. Greek, P. Elliott, J. Nenonen and J.H. MacGregor</i>	813
Brain electromagnetic tomography: A comparative study of the source resolution of electric and magnetic measurements <i>R.D. Pascual-Marqui and R. Biscay-Lirio</i>	741	Biomagnetic inverse solution with a realistic torso model <i>K. Forsman, J. Nenonen, C. Purcell and G. Stroink</i>	819
A high-resolution distributed source model for time-varying spontaneous brain electromagnetic activity <i>R.D. Pascual-Marqui, S.L. Gonzalez-Andino, S. Hampson and B. Lütkenhöner</i>	747	Simple geometrical shapes as volume conductor models in magnetocardiography: Application to clinical and experimental data <i>S. Achenbach, W. Moshage, K. Abraham-Fuchs, R. Graumann, K. Göhl, M. Friedrich and K. Bachmann</i>	825
Reconstruction of current densities with anatomical constraints <i>R. Graumann, K. Abraham-Fuchs, W. Moshage and S. Schneider</i>	753	A finite element model to study the magnetic detection of flutter waves <i>C. Hall Barbosa, P. Costa Ribeiro, E. Costa Monteiro, A.C. Bruno, E. Parente Ribeiro and A. Fonseca Costa</i>	831
Magnetic source imaging by current element distribution <i>M. Shimogawara, H. Kado, H. Kohno and M. Higuchi</i>	757		
Current source image estimation by spatially filtered MEG <i>S.E. Robinson and D.F. Rose</i>	761	INSTRUMENTATION	
Extraction of dynamic patterns from distributed current solutions of brain activity <i>K.D. Singh, A.A. Ioannides, R. Hasson, U. Ribary, F. Lado and R. Llinàs</i>	767	A multichannel SQUID system for current density imaging <i>O. Dössel, B. David, M. Fuchs, W.H. Kullmann, K.-M. Lüdke and J. Krüger</i>	837
Fourier methods in biomagnetic imaging <i>W.J. Dallas, H.A. Schlitt, S.A. Cameron and W.H. Kullmann</i>	773	Twenty-eight channel hybrid neuromagnetometer <i>G. Torrioli, S. Casciardi, C. Del Gratta, V. Foglietti, W.J. Gallagher, M.B. Ketchen, A.W. Kleinsasser, A. Pasquarelli, V. Pizzella, G.L. Romani and R.L. Sandstrom</i>	843
Correlation coefficient scanning to identify localised activity <i>R. Hasson and S.J. Swithenby</i>	779	A 19-channel DC-SQUID based neuromagnetometer <i>H.J.M. ter Brake, J. Flokstra, W. Jaszczuk, E.P. Houwman, D. Veldhuis, R. Stammis, G.K. van Ancum, A. Martinez and H. Rogalla</i>	847
Localization of averaged and unaveraged interictal spike activity in temporal lobe epilepsy with a multichannel MEG <i>P. Schüler, H. Stefan, S. Schneider, K. Abraham-Fuchs and W. Zwerenz</i>	783	Development of a magnetoencephalographic imaging system connected to NMR-CT images of the human head <i>Y. Uchikawa, T. Shiota, M. Kotani, K. Shibata, S. Kajihara, H. Okuyama and H. Wani</i>	853
Improvement of neuromagnetic localization by MCG-artifact correction in MEG recordings <i>K. Abraham-Fuchs, P. Strobach, W. Härer and S. Schneider</i>	787	SQUID-based active shield for biomagnetic measurements <i>K. Matsumoto, Y. Yamagishi, A. Wakusawa, T. Noda, K. Fujioka and Y. Kuraoka</i>	857

Superconducting shield for biomagnetic measurements coupled with ferromagnetic	
<i>H. Matsuba, D. Irisawa and A. Yahara</i>	863
On-line head position determination for MEG measurements	
<i>M. Fuchs and O. Dössel</i>	869
Fast positioning system for a multichannel biomagnetic detector	
<i>F. Incardona, S.N. Ern�, I. Modena and L. Narici</i>	875
Rotatory scanning for improved discrimination of very low frequency components of the magnetoencephalogram	
<i>A.R. Gardner-Medwin</i>	881
Fiber optic movement detector for long-duration	
DC-magnetoencephalography	
<i>G.L. Barkley, S. Eggeraat, J.E. Moran and N. Tepley</i>	887
A new sensory stimulator for the MEG environment: The Piezo undulative multifrequency apparatus (PUMA)	
<i>R. Jagow, U. Ribary, F. Lado and R. Llin�s</i>	891
A low-cost biomagnetic current probe system for the measurement of action currents in biological fibers	
<i>J.M. van Egeraat and J.P. Wikswo Jr.</i>	895
Index of authors	901